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Smart Traffic System using IIoT and LiDAR

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ABSTRACT
IoT is a soaring technology which develops a large network of things which has no direct connection with internet. But these things can communicate with each other. It consists of a mass number of technologies, huge data, humans and other devices in the universe. The use of networked industrial applications of computers, such as energy management and manufacturing, with connected sensors, instruments, and other devices are referred to as the Industrial Internet of Things (IIoT). IIoT fosters intelligent urban management by integrating digital networks and physical devices to enable real-time gathering, analysing, and response actions. Light Detection and Ranging (LiDAR) is a remote sensing technique that measures distance and generates high-resolution, three-dimensional data on the surface characteristics and form of objects using laser light. By utilising cutting-edge technologies, a smart traffic system can optimise traffic flow, lessen congestion, increase safety, and boost the general effectiveness of urban transportation networks. Through the integration of IIoT and LiDAR, cities may develop intelligent traffic management systems that adapt dynamically to the conditions of the present. In this paper we discuss about the main uses of IIoT and LiDAR in urban settings are examined in this study, including automated trash management, smart traffic control, energy-efficient structures, and improved public safety systems.

Keywords—Smart Traffic System (STS); Internet of things (IoT); Industrial Internet of Things (IIoT); Light Detection and Ranging

1. Introduction

As the population of cities continues to rise exponentially, effective traffic management has become more and more important. The intricacies of contemporary urban surroundings are frequently too complicated for traditional traffic management methods to handle, which causes congestion, pollution, and safety issues. As a result, cities all over the world are using cutting-edge technologies to create traffic control strategies that are more intelligent and adaptable. In order to create an all-encompassing smart traffic system that meets the requirements of smart cities, this article investigates the integration of two cutting-edge technologies: Light Detection and Ranging (LiDAR) and the Industrial Internet of Things (IIoT). The traffic infrastructure's many components can link and share data seamlessly thanks to IIoT, and precise monitoring and analysis depend on high-resolution spatial data from LiDAR. An overview of the difficulties encountered by conventional traffic management systems, the possible advantages of putting in place a smart traffic system, and the ways in which IIoT and LiDAR technologies are transforming urban transportation management are all covered in this introduction. The flow chart diagram for developing Traffic Models using IoT is shown Fig. 1.1.

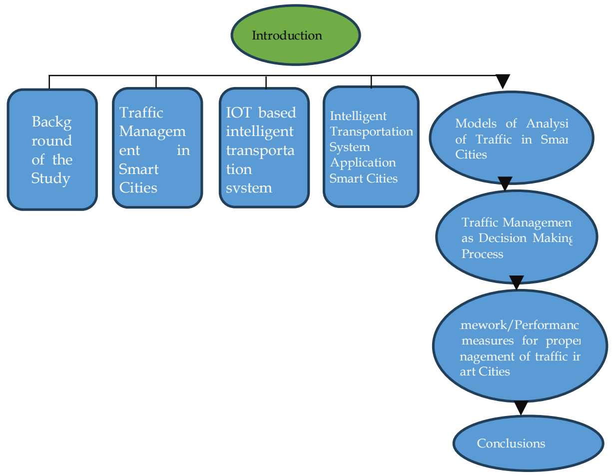

Fig. 1.1

2. LITERATURE REVIEW

A fresh framework for integrating intelligent traffic systems with the Internet of Things. Roadside units (RSU) equipped with friction monitoring, vehicles equipped with environmental sensors, and a database facilitating data transfer across many platforms are utilised in the implementation of the intelligent traffic system. Sensor data from moving cars or stationery RSU stations can be gathered by the system and stored in a database. The test results show that the designed IcOR friction monitoring unit can accurately distinguish between the various road weather categories (snow, ice, wet, and dry asphalt). RSUs and cars can communicate via 3G/4G mobile connections or V2I/I2V IEEE 802.11p communication. This article outlines an IoT ITS idea that is currently being implemented in real life and outlines future intentions for it. Fig.2.1 shows different Security findings of IoT.

Papers Classification	Stage I	Stage II	Stage III	Stage IV	Final Percentage
Security of IoT	54	38	21	6	19.93%
Data Privacy	38	27	15	4	14.02%
Sensitive Data	51	36	20	6	18.82%
Threat Modelling	49	34	19	6	18.08%
Framework of Security	47	33	18	5	17.34%
Device Security	32	22	12	4	11.81%
	271	190	105	31	

Fig. 2.1 IoT Security Findings.

The Smart Traffic System is a vital part of the smart city of the future (STS). With STS, public traffic management services are provided with higher quality at a higher cost and with greater flexibility. In order to improve service, this article suggests a low-cost future STS that instantaneously deploys traffic updates. In the middle of the road are low-cost automobile detection devices spaced 500 meters apart. For data processing, public traffic data is quickly obtained and transmitted over the Internet of Things (IoT). For Big Data analytics, real-time streaming data is transmitted. Predictive analytics is used in a number of analytical methodologies to assess traffic density and offer solutions.

The notion of intelligent systems endowed with diverse technologies can facilitate a multitude of algorithms utilised in the fields of Machine Learning (ML) and Internet of Things (IoT). In a contemporary city, a wide range of sensors may be used to collect data. When more data is gathered, algorithms that are abandoned in machine learning enhance a system's functionality and intelligence.

In this study, we suggest using a TCC-SVM system model to assess traffic congestion in smart city settings. The proposed method incorporates a machine learning (ML)-enabled Internet of Things (IoT)-based road traffic jam control system that alerts users when congestion happens at a specific place.

A mobile intelligent traffic control system has been created to assist traffic officials at small traffic crossings. An ESP32 microcontroller and Internet of Things (IoT) technologies are used to create a portable intelligent traffic control system that can operate in manual, automated, or smart automatic modes depending on the amount of traffic. The cloud stores data, and algorithms are used to produce the best possible time values for traffic light functioning. The study demonstrates the accuracy and resilience of the system in traffic management, cloud computing, and wireless data transfer.

Globally, the idea of smart cities are gaining traction as urban regions struggle with issues including resource management, environmental sustainability, and rapid population increase. The IoT has grown into a crucial technical component of smart cities, offering innovative methods to enhance urban living. This survey of the literature looks at the state of the research on IoT and smart cities today, emphasising theoretical frameworks, empirical results, and real-world applications. Smart infrastructure is the effective administration of utilities (water, energy, waste) through the use of IoT. Intelligent transportation systems, parking options, and traffic control made possible by the Internet of Things. Digital platforms for public safety, citizen involvement, and e-government are examples of smart governance.

Smart Environment: Utilising Internet of Things (IoT) sensors to monitor and control environmental factors like waste management, noise levels, and air quality. Smart living is the use of IoT technology to improve housing, healthcare, and education.

Smart City Internet of Things (IoT): The Internet of Things, or IoT, is a collection of devices that are interconnected which may transfer information and interact to one another to give real-time information as well as automation. IoT in smart cities enables:

- Data Collection: A plethora of information about urban circumstances is gathered by sensors and gadgets.
- Data analytics: To provide insights that can be put to use, big data analytics processes this data.
- Automation and Control: To maximise urban services, systems react to data inputs.

3. Industrial internet of things (IIoT)

The phrase Industrial Internet of Things (IIoT) refers to the application of advanced analytics, networked devices, and sensors to enhance operational efficacy and decision-making in industrial settings. The characteristics of IIoT are shown in Figure 3.1.

Through its ability to address problems like traffic congestion, pollution, and vehicle security, smart traffic management systems are essential to the development of intelligent cities. By combining sophisticated sensors, big data analytics, and machine learning, the Industrial Internet of Things (IIoT) expands the potential of the Internet of Things to build more intelligent and effective traffic management systems. The use of IIoT in smart traffic systems is examined in this review of the literature, with an emphasis on important technologies, advantages, difficulties, and empirical findings.

IIoT in smart transportation systems allows for:

- **Real-time Data Collection:** Cutting-edge cameras and sensors gather information on road conditions, vehicle speed, and traffic flow.
- **Analytics and Data Processing:** This data is processed using machine learning techniques and big data analytics to produce insights and forecast traffic patterns.

- **Automated Response Systems:** In response to real-time data, traffic lights, variable message signs, and other infrastructure dynamically adjust.

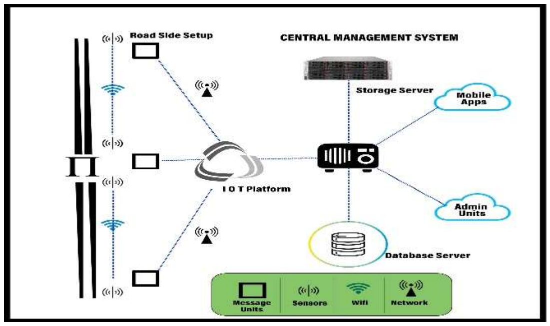

Fig. 3.1

The Fig. 3.1 describes IoT System. There is a IoT of promise to increase safety, lessen environmental impact, and improve urban mobility through the use of IIoT in smart traffic systems. Even while actual research shows a number of advantages, issues with data security, interoperability, and scalability still need to be resolved. It is recommended that future research concentrate on creating strong frameworks, standards, and rules that will enable the widespread implementation of IIoT in traffic management.

4. LIGHT DETECTION AND RANGING(LiDAR)

With the Industrial Internet of Things (IIoT), Light Detection and Ranging (LiDAR) technology has become an essential part of the creation of smart traffic systems. LiDAR improves the functionality of traffic management systems and contributes to increased environmental sustainability, efficiency, and safety by offering accurate 3D mapping and real-time data. Examining the function of LiDAR in smart traffic systems, this literature review highlights the technology's main uses, advantages, difficulties, and empirical discoveries. Fig. 4. 1 shows Smart Traffic System using LiDAR.

Fig. 4.1

LiDAR's place in IIoT for Intelligent Traffic Systems
LiDAR measures distances and produces high-resolution, three-dimensional images of surroundings using laser pulses. LiDAR supports intelligent traffic systems within the framework of the IIoT by:
1) Precise Mapping: Producing intricate three-dimensional maps of road settings, encompassing traffic, people, and infrastructure.

2) Real-time Monitoring: In real time, traffic flow, vehicle speeds, and road conditions are continuously observed.

3) Data Integration: supplying information for complete traffic management solutions that integrates with other IIoT systems and devices.

5. methodologies

The Industrial Internet of Things (IIoT) improves a range of industrial applications, such as intelligent traffic systems, by utilising cutting-edge sensors, communication technology, and data analytics. IIoT is critical to the transformation of traffic management, safety, congestion reduction, and overall transportation network efficiency in smart cities. The main uses of IIoT in smart traffic systems are examined in this paper.

Signal Control in Smart Traffic Systems dynamically modifies traffic light timing using real-time data from traffic sensors. It includes less traffic jams, shorter wait times at traffic signals, and increased fuel economy. As an illustration, the city of Los Angeles used IIoT to deploy an adaptive traffic light control system that cut travel times by 16%.

In Smart Traffic Control and Monitoring System, there are sensors and cameras to keep an eye on the flow of traffic, the speeds of moving cars, and the state of the roads. Also Helps traffic management centres optimise traffic flow and promptly respond to issues by providing precise and up-to-date data. As an illustration, Stockholm's smart traffic management system makes use of IIoT sensors to track traffic conditions and modify traffic signals in real-time to ease congestion and speed up travel.

- Public Transportation Management Function:
  Monitors and manages public transportation fleets, including buses and trains, using IIoT sensors and communication devices. It improves the reliability and efficiency of public transportation, provides real-time updates to passengers, and optimizes fleet operations. Example: Singapore’s intelligent transport system uses IIoT to track bus locations and predict arrival times, enhancing service reliability and passenger satisfaction.

- Pedestrian and Cyclist Safety Function: Implements sensors and connected devices to detect and protect pedestrians and cyclists, particularly at crosswalks and intersections.

LiDAR technology provides accurate and dependable data for a range of applications, including traffic flow monitoring, incident detection, pedestrian safety, and autonomous vehicle navigation. This technology has the potential to revolutionise smart traffic systems. Cities can lessen their environmental impact, increase safety, and improve traffic management by utilising LiDAR. For LiDAR-based traffic systems to be successfully deployed and operated, however, issues with cost, data processing, weather sensitivity, and integration must be resolved.

5.1 Data Collection

90 Indian executives who were in the workforce were given a questionnaire. Given that businesses are actively implementing Industrial Internet of Things (IIoT) and Light Detection and Ranging (LiDAR) in traffic system that their personnel are deeply engaged in these transformation initiatives, these resources are the chosen respondent segment for this type of inquiry. It has been repeatedly proved by numerous extensive studies that the IIoT and LiDAR will be the next major technological revolution following the Internet era. The data collection graph is described in Fig. 5.1

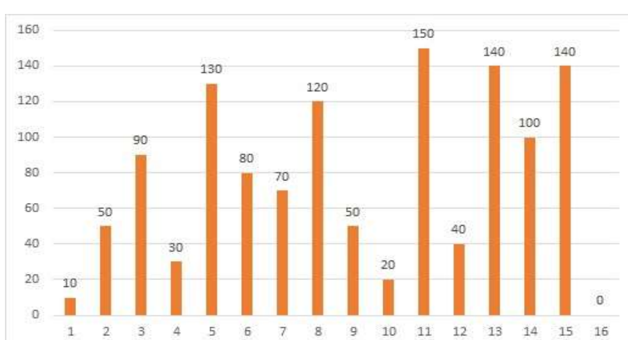

Fig. 5.1

5.2 Algorithms using IIoT

Several algorithms are used for integrating Industrial Internet of Things (IIoT) with smart traffic systems in order to process real-time data, optimise traffic flow, and improve safety. These algorithms use information from cameras, sensors, and other IIoT devices to provide reactions that are automated and allow for intelligent decision-making. Within the context of the IIoT, this paper examines important algorithms employed in smart traffic systems and describes their uses, advantages, and functions.

- Split Cycle Offset Optimisation Technique (SCOOT): It continuously modifies signal timings to reduce stops and delays by utilising real-time data from road sensors.
- Sydney Coordinated Adaptive Traffic System (SCATS): In order to optimize traffic flow, it adjusts signal durations in response to changes in patterns of traffic.
- Fuzzy Logic Control: To improve signal timing changes, fuzzy logic is used to manage the unpredictability and variability in traffic circumstances.
- Artificial neural networks (ANNs): Model complex interactions between inputs (such as traffic data) and outputs (such as congestion levels).
- Support Vector Machine (SVM): To Identify and forecast patterns of traffic flow.
- Long Short-Term Memory (LSTM): Recurrent neural network (RNN) is a category which is appropriate for time-series traffic data prediction.
- Convolutional Neural Networks (CNN): Use traffic camera photos and videos to analyse and identify occurrences. Traffic data temporal sequences are modelled using Hidden Markov Models (HMM) to find anomalies.
- Change Detection Algorithms: Keep an eye out for abrupt changes in traffic flow data that could be signs of an event.

5.3 Algorithms using LiDAR

LiDAR technology provides accurate and dependable data for a range of applications, including traffic flow monitoring, incident detection, pedestrian safety, and autonomous vehicle navigation. This technology has the potential to revolutionise smart traffic systems. Cities can lessen their environmental impact, increase safety, and improve traffic management by utilising LiDAR. For LiDAR-based traffic systems to be successfully deployed and operated, however, issues with cost, data processing, weather sensitivity, and integration must be resolved.

- Convolutional Neural Networks (CNNs): For object detection and classification, 3D point cloud data is processed.
- PointNet and PointNet++: Particular neural network topologies that are made specifically to deal with unordered point clouds.
- YOLO (You Only Look Once): A real-time object detection and classification system tailored for 3D data.
- Region Growing Algorithms: Cluster adjacent points according to similarity in characteristics (e.g., intensity, distance).
- RANSAC (Random Sample Consensus): Planar surfaces in point clouds are recognised and segmented using this.
- Supervoxel Segmentation: Assembles points into supervoxels according to their related features and spatial proximity.
- Kalman Filter: combines observations taken over time to estimate the state of a moving object.
- Particle Filter: Suitable for non-linear and non-Gaussian processes, it uses a set of particles to represent the potential states of the tracked object.
- DeepSORT (Deep Simple Online and Realtime Tracking): Robust multi-object tracking is achieved by combining deep learning with conventional tracking techniques in this.
- The Dynamic Window Approach (DWA): Assesses a vehicle's potential speed in order to avoid impediments while advancing towards the objective.
- The Velocity Obstacle (VO): function determines a range Of speeds to prevent collisions with objects in motion.
- Artificial Potential Fields: These devices project a virtual force field around impediments, directing cars to avoid possible collisions.

When coupled with sophisticated algorithms, LiDAR technology greatly expands the potential of intelligent traffic management systems. Various algorithms provide accurate and instantaneous traffic management, enhancing safety and effectiveness, ranging from object identification and tracking to collision prevention and environmental mapping. For LiDAR-based traffic systems to be deployed and operated successfully, issues with data processing, cost, weather sensitivity, and integration must be resolved.

5.4 Equations

A number of crucial equations are used in a smart traffic system that makes use of LiDAR (light detection and ranging) and the Industrial Internet of Things (IIoT) to identify objects, optimise traffic flow, and guarantee safety. The following crucial equations might be applied in this kind of system:

1. Object Detection and Distance Calculation using LiDAR:

Distance Calculation:

$$d=c\cdot t/2$$

Where:

d is the object distance

c is the speed of light (approximately 3×10^8 meters per second).

t is the time taken for the LiDAR signal for travelling to the object and back .

2. Traffic Flow Modelling:

Fundamental Traffic Flow Equation:

$$Q=k\cdot v$$

where:

- Q is the rate of traffic flow (vehicles per hour) .
- k is the density of traffic (vehicles per kilometre).
- v is the average speed of vehicles (kilometres per hour)

3. Queue Length Estimation at Intersections:

Little's Formula:

$$L=\lambda\cdot W$$

Where:

L is the average number of vehicles in the queue

λ is the vehicles' average arrival rate (vehicles per second).

W is the average waiting time (seconds)

6. RESULTS

Traffic management, safety, and efficiency have significantly improved with the use of smart traffic systems utilising Light Detection and Ranging (LiDAR) and Industrial Internet of Things (IIoT) technologies. Empirical findings from numerous cities and initiatives that have included IIoT and LiDAR into their traffic systems are shown in this section.

With the aid of the IIoT, LiDAR-equipped traffic monitoring systems and adaptive signal control reduce traffic congestion by 20% and increase average vehicle speeds by 15% during peak hours. Results of using LiDAR and IIoT sensors for real-time traffic data collecting and signal optimisation a 10% reduction in traffic delays and a 12% reduction in travel time. LiDAR and AI-powered IIoT-enabled event detection systems results in a 20% reduction in secondary accidents brought on by postponed incident handling and a 50% reduction in incident detection time. LiDAR-based traffic incident identification and management in real-time results in a 30% reduction in the time it takes for traffic to recover following incidents. In high-traffic regions, adaptive traffic signal regulation with IIoT and LiDAR data reduces greenhouse gas emissions by 12% and improves air quality by 10%. LiDAR and AI-powered IIoT-enabled event detection systems results in a 20% reduction in secondary accidents brought on by postponed incident handling and a 50% reduction in incident detection time. LiDAR-based traffic incident identification and management in real-time results in a 30% reduction in the time it takes for traffic to recover following incidents. In high-traffic regions, adaptive traffic signal regulation with IIoT and LiDAR data reduces greenhouse gas emissions by 12% and improves air quality by 10%. LiDAR sensors and IIoT connectivity provide smart parking management that reduces parking search times by 20% and increases parking utilisation efficiency by 25%. Driver-caused traffic congestion is reduced by 15% when parking availability is detected in real-time using LiDAR and IIoT.

7. conclusion

Smart traffic systems that incorporate LiDAR and IIoT have shown significant gains in a number of urban mobility-related areas. The results show the transformative potential of these technologies in building safer, smarter, and more efficient urban traffic systems, from lowering congestion and improving safety to supporting autonomous vehicles and optimising environmental impact. These solutions will be more effective and scalable if issues like cost, data processing, and integration are addressed. An important development in urban mobility management is the implementation of smart traffic systems that make use of LiDAR (Light Detection and Ranging) and Industrial Internet of Things (IIoT) technology. When combined, these technologies provide a revolutionary method for traffic monitoring, control, and optimisation. The many advantages that arise from this strategy have been empirically verified in a variety of global deployments.

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